10/030586
531 Rec'd PCT/PTO 02 JAN 2002
[10191/2175]

FUEL INJECTOR

FIELD OF THE INVENTION

The present invention relates to a fuel injector.

BACKGROUND INFORMATION

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or injection of diesel fuel, a problem may occur; namely, that the downstream tip of the injectors projecting into the combustion chambers may get coked by fuel deposits (that is, soot particles formed in the flame front may deposit on the valve tip). Thus, with injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) may exist over the service life of the injectors, which may lead to disturbances in the running of the internal combustion engine and a failure of the injectors.

SUMMARY OF THE INVENTION

An exemplary fuel injector according to the present invention may have the advantage that the negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber may be reduced or eliminated. The application of coatings on the downstream valve end, especially around the outlet areas of the discharge orifices, may reduce or prevent coking or formation of covering (soot) on the valve end that may negatively influence the spray parameters and the valve function.

It may be advantageous to apply layers on the valve end, by which either a catalytic conversion (burning) of the deposits may be effected or the surface energy and/or the surface roughness of the component to be coated may be reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an exemplary fuel injector according to the present invention inserted into a location bore of a cylinder head.

Figure 2 shows a longitudinal cross-section of an exemplary fuel injector according to the present invention.

Figure 3 shows a valve end coated according to an exemplary embodiment of the present invention.

Figure 4 shows another valve end coated according to an exemplary embodiment of the present invention.

Figure 5 shows an alternative guide and seat area on a valve end at the spray-discharge side.

Figure 6 shows a longitudinal cross section of an exemplary fuel injector according to the present invention for an auto-ignition internal combustion engine.

Figure 7 shows an end of the fuel injector of Figure 6 on the combustion chamber side.

DETAILED DESCRIPTION

Figure 1 shows a cut-off segment of a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition. Formed in cylinder head 1 is a graded location bore 2 that extends symmetrically along a longitudinal axis 4 up to a

combustion chamber 3. A fuel injector 5, according to an exemplary embodiment of the present invention, is inserted into location bore 2 of cylinder head 1. Fuel injector 5 may be used for direct injection of fuel, particularly gasoline, but may also, for example, be used for injection of diesel, as shown in Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 may be actuated electromagnetically via an electrical connecting cable 6. The fuel may be supplied to fuel injector 5 by an intake nipple 7. The fuel injector 5 of Figure 1 is a top-feed injector, in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, the fuel being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near combustion chamber 3 from overheating, injector 5 may be at least partially surrounded, for example, with a thermal-protection sleeve 9 also inserted in location bore 2, although the thermal-protection sleeve may be dispensed with.

Figure 2 shows a cross-section of an exemplary fuel injector 5 according to the present invention. An electromagnetically operable valve, which has a tubular, largely hollow-cylindrical core 11 that is at least partially surrounded by a magnetic coil 10, is used as the internal pole of a magnetic circuit. For example, a graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded by magnetic coil 10, permits a particularly compact and short injector in the area of magnetic coil 10. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15, which extends along a longitudinal valve axis that coincides

with the longitudinal axis 4 of the location bore 2 of Figure 1. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 10 is an outer metallic (such as, for example, ferritic) housing part 16 which, as an external pole or an outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 10, at least in the circumferential direction. Provided in the longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 that filters out fuel components that, because of their size, may cause clogging or damage to the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, may enclose or receive an axially movable valve part including an armature 19, a bar-shaped valve needle 20 and an elongated valve-seat support 21. Both housing parts 16 and 18 may be permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 may be effected, for example, by a sealing ring 22. Valve-seat support 21 includes, over its entire axial extension, an inner through hole 24 that runs concentrically with respect to the longitudinal valve axis.

With its lower end, which also functions as the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped valve-seat element 26, fitted into through hole 24, including a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20, which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

A guide opening 34 provided in valve-seat support 21 at the end facing armature 19 and a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and including a dimensionally accurate guide opening 36 are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 may be predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 10 is not energized, may be established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26. Another end position of valve needle 20, when magnetic coil 10 is energized, may be established by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the stop region may be, for example, chromium-plated.

The electrical contacting of magnetic coil 10, and thus its excitation, may be effected by contact elements 43 ,which, outside of coil form 13, may be provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components (such as, for example, housing parts 16 and 18) of fuel injector 5. Leading out of plastic extrusion coat 44 is electrical connecting cable 6, by which magnetic coil 10 may be energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures guide element 35, swirl element 47 and valve-seat element 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM (electrical discharge machining), laser

cutting, etching or other methods from sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component may be impressed on the fuel to be ejected, so that the flow may enter with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray may be delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem may occur that the downstream tip of the injector projecting into the combustion chamber may get coked by fuel deposits (that is to say, soot particles in the flame front may deposit on the valve tip). Thus, for injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) exists over the service life of the injectors, which may lead to disturbances in the running of the internal combustion engine, up to a failure of the injectors.

According to an exemplary embodiment of the present invention, it is believed that these aforesaid problems may be reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, such as, for example, on valve-seat element 26 made of Cr-steel, may be attained by different coatings. Ultimately, however, these measures are intended to reduce or prevent the coking or formation of covering (soot) on valve end 8, which may have a negative influence on the spray parameters and the valve function. Individual coating possibilities are further described in the following.

Catalytically acting layers may form a first group of coatings. The electrolytically applied layers may provide for

a catalytic conversion (burning) of the deposited soot particles or prevent the deposit of carbon particles. Suitable materials for such a coating to avoid coking may be cobalt, nickel oxides and oxides of alloys of these metals. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals, among themselves or with other metals, may also exhibit catalytic effectiveness. The desired layers may be produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

Coatings with which wetting properties on corresponding surface 54 may be changed, form a second large group of coatings. These coatings may reduced the surface energy and/or the surface roughness of critical regions at valve end 8. The interfacial energy between surface 54 and the fuel may thereby be increased, which causes the wetting to deteriorate. In this way, the fuel drops at the regions coated according to an exemplary embodiment of the present invention may be able to drip off and may be entrained by the surrounding flow at valve end 8. Permanent wetting of valve end 8 may no longer take place. Such layers may be ceramic coatings, carbon coatings, which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings may be, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings may be applied by spraying or dipping. Sapphire coatings may also be applied.

A third group of coatings may be formed, with which a reaction layer may be prevented. Coatings for this third group may be, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace may be deposited on surfaces 54 to be coated.

The regions to be coated at valve end 8 are, in particular, those that immediately surround the at least one discharge orifice 32 in its outlet area 55, since, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge may lead, in particular, to the disadvantageous influencing of the spray parameters (such as, for example, static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above). Thus, a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifice 32 may be formed.

Figures 3 and 4 show bottom views of two exemplary embodiments of valve ends 8 coated according to an exemplary embodiment of the present invention. In Figure 3, entire downstream component surface 54 of the component including discharge orifice 32, shown in Figure 3 as valve-seat element 26, is coated. In Figure 4, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32. The dotted areas show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane (not shown). The coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments of Figures 3 and 4, valve-seat element 26 is the component of fuel injector 5 that forms downstream end 8 and has discharge orifice 32, so that the coating is applied at downstream end face 54 of valve-seat element 26. However, the application of a coating is not limited to a valve-seat element, but rather other valve components that form downstream valve end 5 and thus project into combustion chamber 3 may also include such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated,

so that the actual spray-discharge area may be protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, to show that an exemplary coating according to the present invention may also be applicable to valve designs that differ structurally. In the exemplary embodiment of Figure 5, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 includes discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 may be permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 may be permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating may be applied over entire curved spray-discharge region 66 or directly in a ring shape about outlet area 55 of discharge orifice 32, so that, relative to the longitudinal valve axis, an off-center coating may exist on curved surface 54.

Figure 6 shows a longitudinal cross section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. Valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84, in which piston-shaped valve needle 20 is arranged, which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end of the bore 84 facing combustion chamber 3, forming a valve-seat surface 27 that has a truncated cone shape. Due to a bulge of

the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed, in whose wall at least one discharge orifice 90 is configured that connects blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into two sections. The first section, which has a larger diameter than the second section, faces away from combustion chamber 3 and is guided in bore 84. The second section has a smaller diameter than the first section, a pressure space 86 being formed between the second section and the wall of bore 84, so that pressure space 86 may be filled with fuel under high pressure by an inlet passage 80 formed in valve-retaining member 73 and valve member 72. Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 may be formed, which may be arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 may be able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28 (not shown in Figure 6 or Figure 7), which cooperates with valve-seat surface 27 so that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating may be applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. Further, only curved outer surface 96 of blind hole wall 93 may be provided, which borders blind hole 92 and in

which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.